FALFA FLOWERS TRIPPED
ND MECHANICAL MEANS

R.L. Pharis

lant Science
f Alberta

Reference

TAKEN FROM THIS ROOM

Thesis
1951
37

Ex libris
universitatis
albertaensis

UNIVERSITY OF ALBERTA
LIBRARY

Regulations Regarding Theses and Dissertations

Typescript copies of theses and dissertations for Master's and Doctor's degrees deposited in the University of Alberta Library, as the Official Copy of the Faculty of Graduate Studies, may be consulted in the Reference Reading Room only.

A second copy is on deposit in the Department under whose supervision the work was done. Some Departments are willing to loan their copy to libraries, through the interlibrary loan service of the University of Alberta Library.

These theses and dissertations are to be used only with due regard to priority rights of the author. Written permission of the author and of the Department must be obtained through the University of Alberta Library when extended passages are used. When permission has been granted, credit must appear in the published work.

This thesis or dissertation has been used in accordance with the above regulations by the persons listed below. The borrowing library is obligated to secure the signature of each user.

Please sign below:

Date	Signature	Institution

Digitized by the Internet Archive
in 2017 with funding from
University of Alberta Libraries

https://archive.org/details/seedsettingofalf00robe

THE UNIVERSITY OF ALBERTA

SEED SETTING OF ALFALFA FLOWERS TRIPPED BY BEES AND MECHANICAL MEANS

A DISSERTATION

SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

FACULTY OF AGRICULTURE

DEPARTMENT OF PLANT SCIENCE

by

Robert Leslie Pharis

EDMONTON, ALBERTA

FEBRUARY, 1951

Thesis
1951
37

U N I V E R S I T Y O F A L B E R T A

FACULTY OF AGRICULTURE

DEPARTMENT OF PLANT SCIENCE

The undersigned hereby certify that they have read and recommend to the School of Graduate Studies for acceptance, a thesis entitled, "Seed Setting of Alfalfa Flowers Tripped by Bees and Mechanical Means", submitted by Robert Leslie Pharis, B.Sc., in partial fulfilment of the requirements for the degree of Master of Science.

PROFESSOR John Unrau

PROFESSOR

PROFESSOR

Date Feb. 16, 1951

ABSTRACT

Seed setting from cross-pollination was seven times higher than from self-pollination.

The total exclusion of pollinating insects reduced the yield by 93% of that of open check. Pollinating insects must therefore be an important factor in alfalfa seed production in Alberta.

Bumble bees and leaf-cutter bees were effective trippers under cages. Honey bees proved to be of little consequence when compared with the native trippers. They may increase the amount of automatic tripping. Leaf-cutter bees and bumble bees were found to be efficient cross-pollinators. There were so few flowers tripped in the honey bee cage that no definite conclusions could be drawn regarding their value as cross-pollinators.

The results suggest that bumble bees are somewhat resistant to DDT.

A locally constructed machine designed to trip alfalfa flowers was tested. The raceme studies showed that the machine was an effective tripper, since it tripped up to 63% of the open flowers. The majority of these flowers did not set pods and seed per pod results indicated that a high degree of self-pollination occurs when flowers are tripped with this machine. Seed yields from the machine treated strips differed only slightly from those of untreated material.

TABLE OF CONTENTS

	Page
INTRODUCTION	1
REVIEW OF LITERATURE	2
Tripping	2
Cross- and Self-Pollination	2
The Importance of Bees	5
Mechanical Tripping	7
Lygus	8
DDT and Bees	9
MATERIAL AND METHODS	10
Test of Honey Bees, Leaf-Cutter Bees and Bumble Bees, and Controlled Selfing and Crossing	10
Test with the Coutts-Evjen Yield Builder	11
Test of Forage Yield	16
Preliminary Studies of the Effect of DDT on Bees	16
RESULTS AND DISCUSSION	17
The Effect of Different Treatments on Alfalfa Seed Setting	17
Cross- and Self-Pollination	17
The Exclusion of Pollinating Insects	21
The Influence of Honey Bees	22

TABLE OF CONTENTS (Continued)

Page

RESULTS AND DISCUSSION (Continued)

The Influence of Leaf-Cutter Bees 27

The Influence of Bumble Bees 29

Seed Setting Under Natural Conditions 30

General Observations 32

Test with the Coutts-Evjen Yield Builder 33

Seed Yields from Strip Treatments 33

Flower Study with the Coutts-Evjen Yield Builder 34

Test of Seedling Yields from Seed Obtained by Different Methods of Pollination 40

The Effect of DDT on Bumble Bees 42

SUMMARY 43

ACKNOWLEDGEMENTS 44

REFERENCES 45

INTRODUCTION

Variability in seed setting continues to be the greatest problem in alfalfa seed production. Among growers and research men there is still no unanimity of opinion on such questions as automatic versus insect tripping, and the importance of cross- over self-pollination. Furthermore, recent investigations have raised questions regarding the importance of the various species of bees as trippers and pollinators.

From time to time, farmers and scientists have attempted to increase seed yield on a commercial basis by constructing tripping machines. Such a machine was locally manufactured and made available for testing.

Lygus bugs are now known to be responsible for a total loss of yield in some Alberta areas. DDT gives satisfactory control, but the effect of this insecticide on beneficial bees has not been fully ascertained.

In this study self- and cross-pollination were compared with the tripping and pollination of leaf-cutter bees, honey bees and bumble bees.

The machine was tested to determine whether the mechanical tripping would be followed by seed setting, and if the seed would result from self- or cross-pollination.

A preliminary investigation was undertaken to study the effect of DDT on the activity of alfalfa-pollinating bees.

REVIEW OF LITERATURE

Tripping

Tysdal (28), Hadfield and Calder (10), and Piper and co-workers (20), believe that under field conditions tripping is necessary for seed setting in alfalfa.

Brink and Cooper (4) showed that fertilization can occur in the untripped flower. Tysdal (28), who reviews the findings of other workers, admits that some fertilization may take place in this manner but that it is the exceptional case and is of little importance in commercial seed production.

Cross- and Self-Pollination

Piper (20), Tysdal (27), Bolton (2) and Knowles (13), found a reduction in the number of pods set and the number of seeds per pod following self-fertilization as compared with cross-fertilization. Thus Tysdal (27) obtained 92% more pods and 56% more seeds from cross-pollinated than from self-pollinated flowers. Similarly Knowles (13) obtained an average of 3.70 seeds per cross-pollinated flower and .56 seeds per self-pollinated flower in random Grimm selections.

Lesins (14) compared cross- with self-pollination under natural conditions in central Sweden. Cross-pollination increased the average pod setting by 2.24, seed setting by 5.20 and seeds per pod by 2.32 times over self-pollination. Bolton (2) working with material selected for high seed setting crossed 30 and selfed 30 flowers on each of 107 plants. He obtained an average of 5.54 seeds per crossed flower and 1.58 seeds per selfed flower. This indicates that selfing results in fewer seeds per pod than crossing.

If seed yield alone were considered, augmenting the natural seed set with a method that would bring about tripping and subsequent self-fertilization would seem of value. Investigations indicate, however, that self-fertilization lowers the seed and forage productivity of the inbred progeny. Tysdal, Kiesselbach and Westover (29) found the actual reduction of yield to be 32% for forage and 38% for seed from one generation of selfing. Hadfield and Calder (10) found in New Zealand that self-fertilization caused a decrease in seed and forage yields of subsequent generations.

Cooper, Brink and Albrecht (7) and Brink and Cooper (5, 6, 8), studied histologically fertilization in alfalfa. The preliminary account (5) indicates that more seed may be formed after cross- than after self-pollination because of partial self-incompatibility; that is, the male gametophytes are less effective

in accomplishing fertilization in plants from which they arise than they are in unrelated individuals. There is also a difference in survival of ovules containing inbred and hybrid embryos and endosperms. Inbred embryos more frequently collapsed during early development than did those resulting from cross-pollination. Brink and Cooper (6, 8) further found that 66.3% of the crossed ovules became fertile, compared with only 14.6% of the selfed ovules. This was attributed to more extensive growth of the tubes from foreign pollen which enabled a higher proportion to reach the ovules, enter the microphyle and accomplish fertilization. They (8) found a rather uniform decline in ovule fertility from apex to base of the ovary. The gradient followed an almost parallel course for both the self- and cross-pollinated series, although the proportion of ovules becoming fertile in each position was considerably higher in the cross-pollinated series. They conclude that the partial self-incompatibility associated with self-pollination and the high incidence of ovule abortion resulting from inbred embryos accounts for the difference in seed production following crossing and selfing.

Stevenson and Bolton (25) indicate that self-tripping, self-fertile alfalfa plants are undesirable as a source of breeding material for improving the seed yield.

The Importance of Bees

Knowles (13) and others (9, 31) report a decrease in seed yield when insects are excluded from alfalfa plants. Jones and Olsen (12) indicated that bumble bees in cages increased the seed set from 3.6% to 18.8%. Knowles (13) reports a decrease from .90 seeds per uncaged flower to .11 seeds per caged flower. He concluded that the decrease was due primarily to the exclusion of bees rather than a change in environmental factors caused by caging. He believed that certain members of the genus Megachile are the most important trippers of alfalfa since they visited and tripped an average of 17.3 flowers per minute. Bumble bees were efficient trippers but were present in insufficient numbers to be as important as leaf-cutter bees. Honey bees were of little importance in the tripping of alfalfa flowers in Saskatchewan.

Tysdal (27) concluded that wild bees are the main factor in alfalfa seed production and that certain members of the genera Megachile and Nomia were the most important in the United States. He describes a noticeable decrease in seed yield corresponding to a related reduction in numbers of wild bees in the seed producing areas of the United States. In his studies he found that leaf-cutter bees tripped 84% of the flowers visited, bumble bees tripped 38-80%, while honey bees tripped only 1.1% of the flowers visited.

Akerberg and Lesins (1) working in central Sweden, rate bumble bees at 78%, leaf-cutter bees at 100% and honey bees at 0.83% efficient.

There are reports that under certain conditions honey bees may be important trippers and pollinators of alfalfa flowers. Vansell and Todd (30) report that honey bees are the main trippers in Millard county, Utah. Their explanation of this phenomena is based on pollen availability and competition. In Millard county, however, there are few pollen sources competing with alfalfa. Corn and greasewood are actually the only important competitors. Corn pollen is available to the bees only on humid mornings, while greasewood pollen is gathered only in the late afternoon. Thus the alfalfa flower is the bees only pollen source during the warm period of the day when the bees are most active. Hare and Vansell (11), also working in Millard county, observed honey bees tripping alfalfa flowers. Observation taken at hives situated strategically in the area showed that alfalfa pollen comprised 32% of the total collected over a three week period in 1944. Pedersen and Todd (19) in a test with potted plants situated near the apiary report that 77% of the nectar collectors working through the "throat" bring about tripping. They state further that the majority of the honey bees gather nectar through the side openings of the flower.

Dwyer and Allman (9) indicate that honey bees are of importance in alfalfa seed production in New South Wales.

Linsley (15), Linsley and MacSwain (16), point out that in California, alfalfa seed production is dependent on the activity of pollinating bees. During the summer of 1945 most of the pollinating bees were native species. In 1946 however, pollen gathering honey bees were mainly responsible for the cross-pollination that occurred.

Stevenson (24) indicates that in Canada the most important insect pollinators are the wild bees. The largest populations of these beneficial insects are found in the newer agricultural areas, this, he feels, accounts for the higher seed yields obtained in these districts. He believes that the populations of these insects are entirely inadequate in older more settled districts.

Mechanical Tripping

Tysdal (28) mentions that a number of mechanical devices have been used to trip alfalfa flowers in an attempt to increase seed setting. He feels, that to be of value, the machine must cross-pollinate as it trips the flowers.

Silversides and Olson (21) tried a number of mechanical devices that met with little success. While the amount

of tripping was increased, seed set was less than that of the untreated check. Jones and Olson (12) used a machine with two vertical rotating rollers. Tripping was caused by the pressure exerted on the flowers as they were passed between the rollers. Various materials used as covers for the rollers were compared for pollen carrying ability. Tripping was increased from 11% in the check to 53.5% for the most intensive treatment. Unfortunately no seed yields were obtained. In a personal communication Dr. Olson informed the writer that in later trials this machine had proved unsatisfactory.

Lygus

Sorenson (23) in his studies in Utah found that correlated with an increased concentration of lygus bugs there is an increase of blasted buds, flower drop and shrivelled seeds. Stitt (26), using cages, obtained an average destruction of 23.35 seeds per individual lygus. He obtained a significant positive correlation between the percentage of brown seeds and lygus bug concentration. Similar results were obtained by Bolton and Peck (3). Stitt (26) indicates that the preferred habitat of the lygus is the tender terminal part of the alfalfa

plant where it causes serious damage to the flowering parts and to the developing embryos. Pedersen and Todd (18) found that practical protection against lygus damage to alfalfa could be obtained by the application of 20 lbs. of 10% DDT (dichlorodiphenyl trichloroethane) dust per acre during the pre-bloom period.

DDT and Bees

The observations of Linsley and MacSwain (17) with DDT and its effect on bees are of interest. DDT appeared to repel honey bees, since the number of visitations fell rapidly after the dusting. Coincident with this, there was an increase in the numbers of honey bees visiting the untreated part of the fields. Gradually the population built up in the treated area until in three or four days after treatment it was equal to, or higher than that of the untreated plots. The population of native bees did not decrease as did honey bees. Smith et al (22) demonstrated that 40 lbs. of 5% DDT dust per acre applied three times during the bloom season has a small but detrimental effect on the honey production and activity of honey bees. They felt that this effect was offset by the increased nectar flow resulting from lygus control.

MATERIAL AND METHODS

Test of Honey Bees, Leaf-Cutter Bees and Bumble Bees, and Controlled Selfing and Crossing

This study was carried in a field on the farm of Mr. K. McKenzie of Tiger Lily. This district has been one of the surer seed setting areas of Alberta.

Four wire screen cages of 3 ft. by 3 ft. by 3 ft. dimensions were placed on the field during the latter part of June prior to flowering. The following studies were conducted:

A. Uncaged check.
B. Excluding all pollinating bees.
C. Containing five honey bees.
D. Containing five bumble bees.
E. Containing five leaf-cutter bees.

Actively working bees of the various species were captured and put into the respective cages. In treatments C, D and E, the insects were released after 24 hours and freshly caught bees introduced.

In each treatment 25 racemes of fresh untripped flowers were tagged and the total number of flowers counted prior

to introduction of the various species of bees. The flowers on 25 racemes were tripped and selfed by means of a toothpick, a fresh toothpick being used for each plant. Controlled cross-pollination was performed by collecting pollen from unrelated plants on toothpicks and tripping the fresh flowers of 25 racemes on these toothpicks.

Records were obtained of each flower in all treatments from flowering to wilting or pod setting. At maturity the racemes were harvested, the number of pods were recorded and a count made of the number of seeds in each pod.

The entire growth under each cage was harvested at maturity and yields of seed were obtained. The caged and uncaged check material was harvested and handled in a similar manner.

Test With the Coutts-Evjen Yield Builder

The principle of this machine was developed on a pilot model by Mr. Evjen, a farmer of the Stony Plain district. The Coutts Machine Co. Ltd. of Edmonton manufactured a field scale model in 1949-50. The principle is that of vertical, sponge rubber-covered rollers working in pairs. As the machine moves along the top growth is passed between a pair of rotating rollers. The pressure and shearing force of the rollers accomplishes the tripping. The machine is illustrated in Figs. 1, 2, and 3.

Fig. 1

The Coutts-Evjen yield builder.

Fig. 2

View showing the mechanics of the machine.

Fig. 3

A close-up of the sponge covered rollers which rotate at different speeds, the shearing force plus the pressure between the twin rollers causes some of the flowers to trip as the growth passes between them.

The machine was tested at two different locations. One series of tests was conducted in the Tiger Lily area under seed setting conditions described earlier. It was felt that the machine should also be tested in an area where alfalfa does not usually set seed, as in the immediate Edmonton district. Such a field was made available for testing purposes by Mr. Sharpe of Edmonton. Owing to transportation difficulties, the strip tests were not exactly comparable in both locations.

The following strip tests were conducted with the machine at the Sharpe farm:

1. Once over.
   (1a) Half of one treated once again at a later date.
2. Twice over.
   (2a) Half of two treated once again at a later date.
3. Three times over.
   (3a) Half of three treated once again at a later date.
4. (a) Once over.
   (b) Over a second time at a later date.
   (c) Over a third time at a later date.
5. Checks.
   Two untreated check strips were left, one between treatments 1 and 2, and one between treatments 3 and 4.

Strips in Mr. McKenzie's field were treated as follows:

1. Check strip.
2. Once over.
3. Twice over.
4. Three times over.
5. Twice over at different dates.

Tripping and subsequent seed setting in machine treated material was studied in the following manner: At Tiger Lily, prior to treatment with the machine, 25 racemes, from which all pods, tripped flowers and buds were removed, were tagged. Immediately after treatment the flowers tripped by the machine were counted and all untripped flowers were removed. At Edmonton, racemes were tagged and records taken only in the strips that had been treated once. In September all tagged racemes were harvested, the number of pods per raceme and the number of seeds per pod recorded.

Seed yields from the treated and untreated strips were computed on the basis of the seed weight from 10 one square yard samples harvested from each strip.

Test of Forage Yield

A test was carried out in the greenhouse comparing the green weight of fresh material from seed obtained from the open check, from known selfing, from known crossing, and from flowers tripped by the machine. The experimental design was a 4 x 4 Latin Square.

Preliminary Studies of the Effect of DDT on Bees

Cages similar to those described were used. Into one cage six bumble bees were introduced immediately after application of 10% DDT dust to the enclosed plant material. Into a second cage, six bumble bees were introduced two days after the DDT treatment. Observations were made periodically to determine the effect the DDT had on the bees.

RESULTS AND DISCUSSION

The Effect of Different Treatments on Alfalfa Seed Setting

In Table 1 the data on tripping, pod setting and seed setting are summarized.

Cross- and Self-Pollination

The results from Table 1 indicate the importance of tripping followed by cross-pollination as contrasted with self-pollination. Selfing resulted in pod setting of only 31.6% of the total flowers. Moreover, the pods that were formed contained an average of only 1.7 seeds per pod. Table 2 indicates however, that there were two pods that contained five seeds. These may have been from plants that were more self-compatible than average Grimm plants. If tripping were followed by selfing, a relatively small proportion of the flowers would form pods, these pods would in turn contain relatively few seeds, as illustrated in Fig. 4.

Table 1

The Effect of Different Treatments on Tripping, Pod and Seed Setting in Alfalfa

Treatment	Flowers			Pod setting			Seed setting			
	No. studied	No. tripped	Tripping in %	Total	% of total flowers	% of tripped flowers	Total	Seeds per pod	Seeds per tripped flower	Seeds per total flower
Uncaged check	419	193	46.1	97	23.2	50	426	4.4	2.0	1.02
Caged check	383	3	.8	3	.8	100	5	1.7	1.7	.01
Caged honey bees	473	12	2.5	7	1.5	58	26	3.7	2.2	.06
Caged bumble bees	420	379	90.2	234	55.7	62	1043	4.5	2.8	2.48
Caged leaf-cutter bees	467	285	61.0	181	38.8	64	807	4.5	2.8	1.73
Selfed	345	345	--	109	31.6	32	185	1.7	.5	.54
Crossed	329	329	--	246	74.8	75	1162	4.7	3.5	3.53

Table 2

Frequency Distribution of Pods Containing a Certain Number of Seeds in Each Treatment. (Tiger Lily data only).

Treatment	Number of seeds per pod										
	1	2	3	4	5	6	7	8	9	10	11
Selfing	35	22	10	1	2						
Crossing	4	13	17	10	9	8	12	5	10	5	1
Caged check	1	2									
Caged honey bees	3	1				2			1		
Caged leaf-cutter bees	10	11	12	12	9	6	10	5	8	5	1
Caged bumble bees	9	9	17	13	11	13	9	7	7	2	
Uncaged check	8	9	6	10	7	10	6	6	2	6	1
Coutts machine											
Once over	9	8	5					2			
Twice over	10	9	9	2	2	2					
Three times over	22	14	11	5	2	1	2			1	

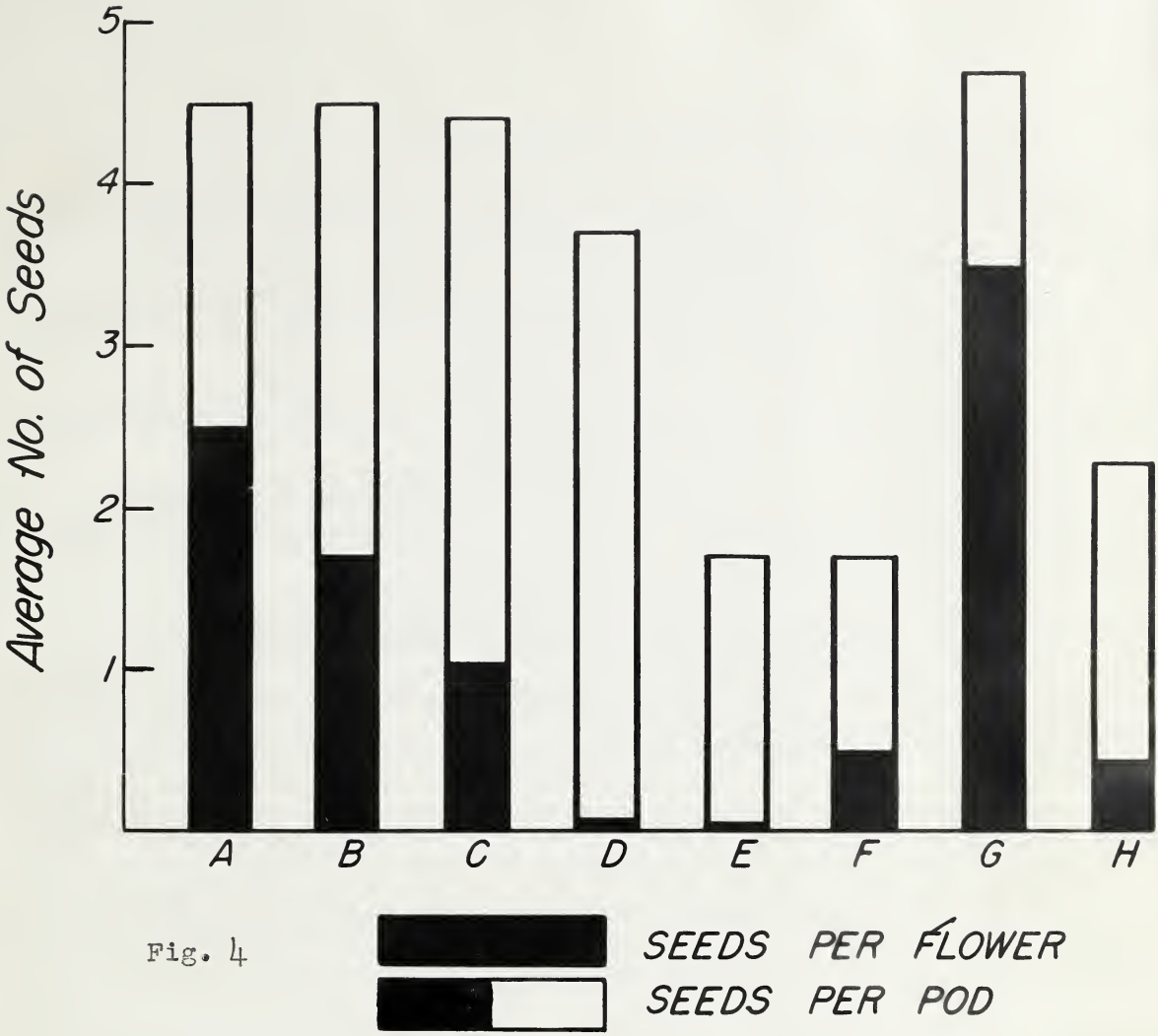

Fig. 4

A Caged Bumble Bees
B Caged Leaf Cutters
C Uncaged Check
D Caged Honey Bees
E Caged Check
F Selfed Flowers
G Crossed Flowers
H Mechanical Tripper

The results of tripping followed by crossing are strikingly different from those of selfing. Pods formed from 74.8% of the treated flowers. In this treatment the major proportion of the pods contained more than three seeds per pod as indicated in Table 2. As can be seen from Fig. 5, the [illegible] appearance of racemes and pods corresponds with the actual counts of the number of pod sets and also of seeds per pod. These results suggest that very likely most of the pods which had three or more seeds were the result of cross-pollination while those with two or less were the result of self-pollination. This interpretation appears valid since as can be seen from Table 2, the majority of the pods resulting from self-pollination had from one to two seeds per pod while those resulting from cross-pollination had three or more seeds per pod. These results are in agreement with those obtained by other workers (5, 13, 20). It is likely that the number of seeds per pod is a reliable criterion for determining the type of pollination that has taken place.

The Exclusion of Pollinating Insects

When all insects were excluded, only three out of 383 flowers under study were tripped. These three formed pods containing only one or two seeds. The results [illegible] expressed in Table 3 show

that some automatic tripping occurred after observation was discontinued, or that a pod set without tripping since there was no record of tripping of the flower concerned.

Table 3

Comparison of Automatic Tripping Occurring in the Cage Checked (B) and the Cage that Contained Honey Bees (C)

	Flowers tripped during five-day period	Pods Forming		Flowers known to trip automatically	Total yield of caged area
		During 5 days	Total		
B	3	3	4	4	1.6 Grams
C	12	7	15	8	1.5 "

The Influence of Honey Bees

Honey bees are of little value as trippers as indicated strikingly in Fig. 6. From Table 1 it can be seen that only 12 of the 473 flowers under study were tripped during the five days that they were exposed to honey bees. Throughout this study honey bees were observed many times in alfalfa fields but in no case were they seen to trip flowers at the time they visited

them. Furthermore pollen gathering honey bees were not seen in alfalfa fields during the course of this study. Seven of the 12 flowers tripped set pods producing 26 seeds. Twenty three of these seeds were in three pods on raceme No. 10 shown in Figs. 6 and 7. It does not appear reasonable to assume that these flowers on raceme No. 10, which resulted in what were obviously pods from cross-pollination (see Table 2), were actually tripped by honey bees. It is more likely that a honey bee visited an automatically tripped flower and became covered with pollen unrelated to that of the flowers on raceme 10. Later the bee visited raceme 10, upon which four flowers had tripped automatically and brought about cross-pollination, which would account for the high number of seeds developed in these pods.

As in the caged check, pod setting occurred from some tagged flowers after removal of the bees and after close observation had been discontinued. The interesting and probably highly important point is that more automatic tripping occurred in the caged honey bee treatment after the removal of the bees than occurred throughout the entire test in the caged check. As is indicated in Table 3, eight pods resulted from flowers which were tripped after the removal of the honey bees. These findings agree with those of Lesins (14), who reports that nectar collecting honey bees increases the amount of automatic tripping. Though there was

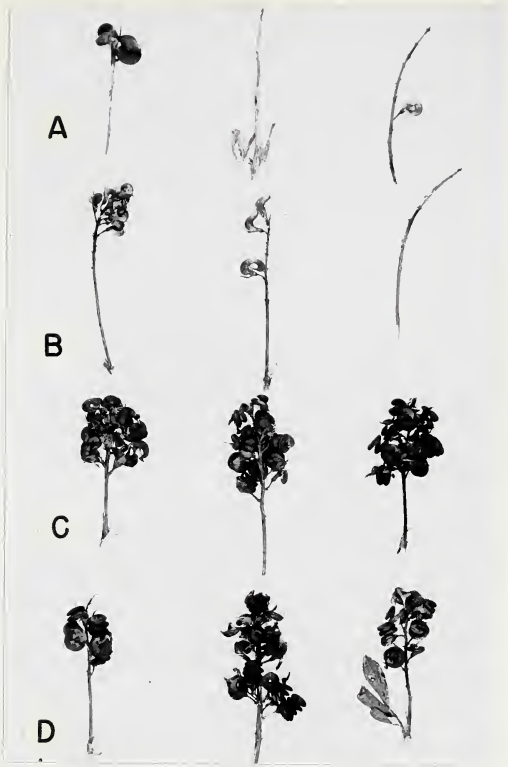

Fig. 5

A. Racemes showing the few pods which developed after the flowers had been tripped by the mechanical tripper.

B. Racemes on which the flowers were selfed by tripping on a clean toothpick.

C. Racemes on which the flowers were tripped on to a toothpick laden with unrelated pollen.

D. Racemes taken from the open check.

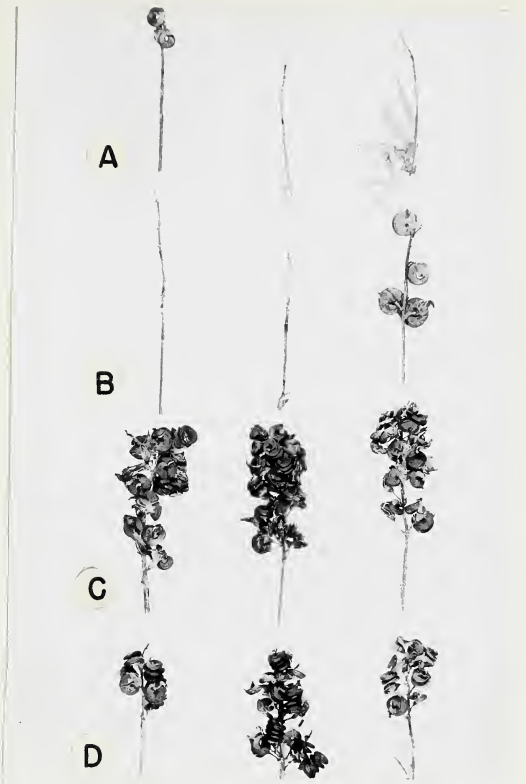

Fig. 6

A. Racemes from the caged check.

B. Racemes from the cage that contained honey bees.

C. Racemes from the cage that contained bumble bees.

D. Racemes taken from the open check.

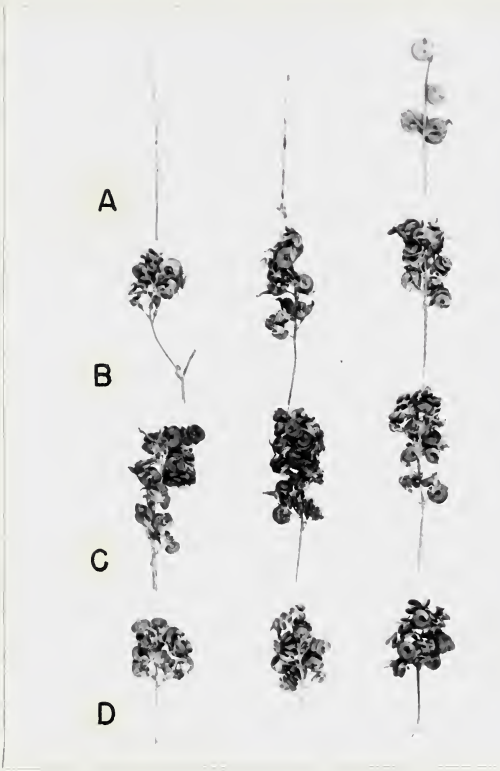

Fig. 7

A. Racemes from the cage that contained honey bees.

B. Racemes from the cage that contained leaf-cutter bees.

C. Racemes from the cage that contained bumble bees.

D. Racemes from controlled cross-pollination.

very little difference in the total amount of seed produced under the two treatments it may well be that if honey bees had been kept in the cage for a longer period of time the yield would have been higher. The increase would not have been great, however, because the automatically tripped flowers would be self-pollinated. A possible explanation of the increase in automatic tripping due to the presence of honey bees may be that the removal of the nectar causes a loss in turgidity which might bring about more automatic tripping.

The Influence of Leaf-Cutter Bees

Caged leaf-cutter bees tripped 61.0% of the flowers under observation. This figure is lower than that for bumble bees (Fig. 8). The difference is probably a cage as well as a temperature effect. During the course of this study it was noted that these bees were seldom observed working at temperatures below 70°F. In addition, the leaf-cutter bee prefers to trip only a few flowers on each raceme it visits. In the course of pollen gathering they fly far and fast. The effect of caging undoubtedly upset their normal behavior. Consequently they spent most of their time trying to escape, and

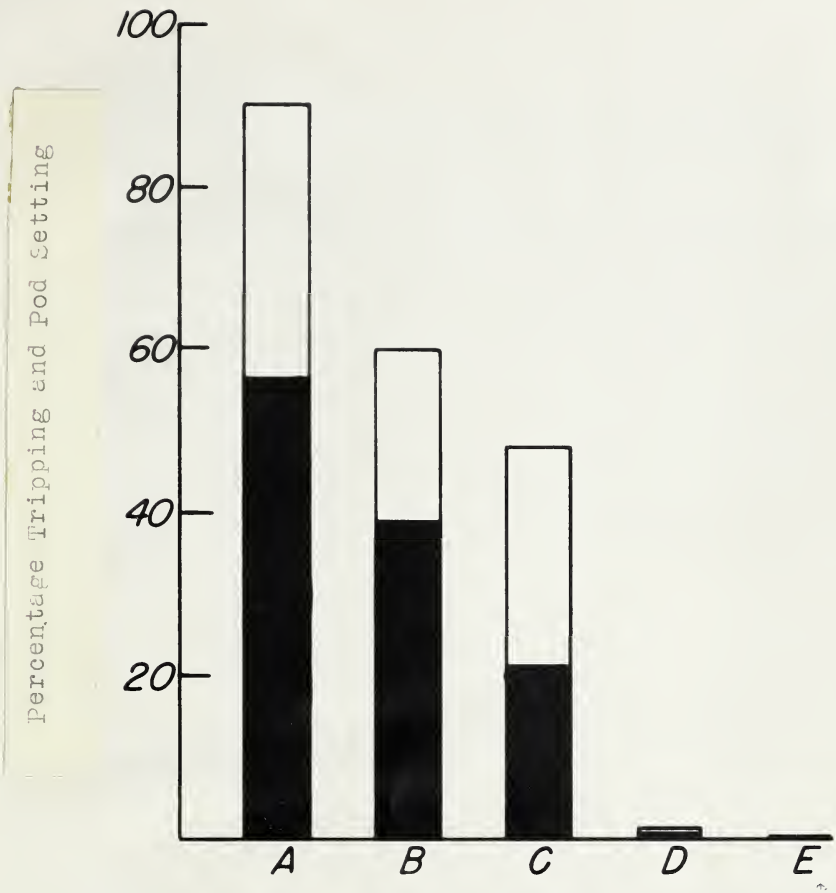

Fig. 8

A Caged Bumble Bees
B Caged Leaf Cutters
C Uncaged Check
D Caged Honey Bees
E Caged Check

worked relatively fewer hours than did the bumble bees. The percentage of tripped flowers forming pods is 64%. This high value and the distribution frequency in Table 2 indicates that these bees are efficient cross-pollinators. This is further substantiated by the data of seeds per pod. Pods from leaf-cutter bee tripped flowers contained an average of 4.5 seeds which is almost identical to the number of seeds resulting from known cross-pollination. (See Figs. 4 and 7).

The Influence of Bumble Bees

It can be seen from Table 1, Fig. 8, that bumble bees are very efficient trippers of alfalfa flowers under caged conditions. These bees tripped 90.2% of the tagged flowers. Of the tripped flowers, 62% set pods. It is possible that this latter percentage would be higher under natural conditions, since near the end of the observation period few fresh flowers remained and some of the flowers tripped were not in the best physiological condition for seed setting. The data on the number of seeds per pod (Table 2, Fig. 4) indicates that the majority of pods formed from bumble bee tripped flowers were the result of cross-pollination. Figs. 5 and 7 illustrate strikingly the difference between racemes from the bumble bee

cages and those from known self-pollinated flowers as well as their similarity to the racemes upon which the flowers were known to be cross-pollinated.

Fig. 8 shows that under cages bumble bees are the superior trippers. This may be a temperature effect. Throughout this investigation it was noticed that bumble bees could be found tripping alfalfa flowers when the temperature was no higher than 50°F. The increased tripping of the caged bumble bees may in part be due to their ability to work at lower temperatures. Not all bumble bees are pollen gathers. The pollen gatherers can be readily distinguished in the field by the large loads of pollen they carry on their legs. Those that seek only nectar enter the alfalfa flower through the side openings, as do the nectar collecting honey bees, and while visiting them seldom trip the flowers.

Seed Setting Under Natural Conditions

Of the total flowers studied in the uncaged check, 46.1% were tripped. This is a high percentage for natural conditions and is undoubtedly due to the large number of tripping insects present in this field at the time of flowering.

The percentage of tripped flowers setting pods is lower for the uncaged check than for the bumble bee and leaf-cutter bee treatments. If bees are responsible for most of the tripping occurring under natural conditions we should expect to find a fairly close relationship between the three mentioned treatments. It may be that the lower pod setting percentage in the uncaged check material was caused by the effects of temperature and plant condition. The season of 1950 was extremely dry and the shade afforded by the cages may have reduced the moisture loss. The growth under the cages was more vigorous and the flowers were larger and appeared fresher. They may have been physiologically more suited to pod production.

The seeds per pod data in Table 1, Table 2, and Fig. 4, indicate conclusively that the majority of the tripping occurring under natural conditions was accompanied by cross-pollination. Since little automatic tripping occurs, and since it has been shown that wind pollination can be disregarded (31), the pollen collecting bee must be the agent which trips the flowers and carries the pollen from flower to flower.

The yield of this field was approximately 255 pounds per acre. The calculated yield of the caged bumble bee treatment was 213 pounds per acre. It should be pointed out, however, that this seed was produced from only those flowers which

were open during the five days that the bees were in the cages. A much higher yield would have resulted had the bees been kept in the cages during the entire period of flowering. Had this population been equalled under natural conditions during the entire flowering period, the yield would have been much higher.

General Observations

The major proportion of the seed set in this field was due to the tripping and cross-pollination brought about by bumble bees. Leaf-cutter bees were present but in insufficient numbers to be of importance. Bumble bees are a social species and it would seem that any program directed at increasing bee numbers should include a study of means of aiding the bumble bees in producing strong healthy colonies. Leaf-cutter bees are solitary and nest in beetle holes in timber and in hard ground. Numerous leaf-cutter bee nests were found in the roadway through the alfalfa field. A roadway would not appear to be a safe or intelligent place to put a nest but unless more suitable requirements are provided the bees will be forced to accept such undesirable nesting sites.

Weather conditions are important because they directly influence bee activity. If the weather is cold during the alfalfa flowering period, the bees are unable to work. The result will be that little seed is set under such conditions.

Bees are exacting in their pollen requirements. Sweet clover and fireweed pollen is more attractive to bees than alfalfa pollen (31). Consequently when these plants are growing near an alfalfa field the bees will likely visit them in preference to alfalfa. The control of these competing pollen sources would appear to be an important part of alfalfa seed production.

It is a common practice in land clearing to windrow and burn the felled trees. Undoubtedly this is a near sighted practice since leaf-cutter bees nest in holes in timber.

Test With the Coutts-Evjen Yield Builder

Seed Yields from Strip Treatments

In Table 4 the results of the tests with the mechanical tripper on the McKenzie farm are summarized. It is obvious that the use of the tripping machine neither increased or decreased

the amount of seed that was set. Actually all the machine treated strips yielded less seed than the check, although in no cases were the differences significant.

The results from tests on the Sharpe farm (Table 5), likewise, were inconclusive. Only in one case, that of the twice over followed by once over at a later date, was the yield actually higher than the check. In this case the yield was not significantly higher than from the check strip closest to it.

The mechanical tripper cannot be discarded on the basis of these tests alone but there are strong indications that its value as a builder of alfalfa seed is questionable. The results, especially in the Sharpe field, indicate that variability due to factors other than the machine had a greater effect upon seed yield. A gradient occurred in this field which accounts for the yield increase between Check I and Check II. In addition, there was considerable variation between the yield of replicate square yard samples.

Flower Study with the Coutts-Evjen Yield Builder

In Table 6 the results from the tagged raceme studies with the mechanical tripper are summarized. The machine accomplishes very effectively the purpose for which it was designed and built. The percentage tripping and the pod setting

Table 4

Seed Yield of Strips Treated by the Coutts-Evjen Yield Builder

(McKenzie Field)

Treatment	Mean yield of ten one-sq. yd. samples (gms.)	S.E.	treatments compared with check for significance
Check	24.1	2.73	
Once over	21.6	1.91	N.S.
Twice over	20.6	2.14	N.S.
Three times over	22.6	2.54	N.S.
Twice over at different dates	22.5	4.60	N.S.

Table 5

Seed Yield of Strips Treated by the Coutts-Evjen Yield Builder

(Sharpe Field)

Treatments	Mean yield of ten one-sq. yd. samples (gms.)	S.E.	Treatments compared for significance with: Check I.	Check II
Once over	4.5	.54	N.S.	5%
Twice over at different dates	4.5	.87	N.S.	5%
Check	6.5	1.41	N.S.	N.S.
Twice over	6.3	.55	N.S.	N.S.
Twice over once over again	10.1	.55	5%	N.S.
Three times over	4.8	.53	N.S.	N.S.
Three times over once over again	8.2	.94	N.S.	N.S.
Check II	8.9	.98	N.S.	N.S.
Three times over different dates	8.6	1.00	N.S.	N.S.

Table 6

The Effect of the Mechanical Tripper on Tripping, Pod and Seed Setting of Alfalfa

Treatment	Flowers			Pod setting			Seed setting			
	No. studied	No. tripped	Tripping in %	Total	% of total flowers	% of tripped flowers	Total	Seeds per pod	Seeds per tripped flower	Seeds per total flower
McKenzie Field										
Machine										
Once over	195	55	28.2	26	13.3	47	62	2.4	1.1	.3
Twice over	209	106	50.7	34	16.3	32	76	2.2	.7	.4
Three times over	230	145	63.0	70	30.4	48	164	2.3	1.1	.7
Selfed by toothpick	345	345	--	109	31.6	32	185	1.7	.5	.5
Crossed by "	329	329	--	246	74.8	75	1162	4.7	3.5	3.5
Uncaged check	419	193	46.1	97	23.2	50	426	4.4	2.0	1.0
Sharpe Field										
Machine										
Once over	778	361	46.3	105	13.5	29	193	1.8	.5	.3
Selfed by toothpick	296	296	--	131	44.3	44	203	1.6	.7	.7
Crossed by "	288	288	--	181	62.8	63	721	4.0	2.5	2.5

of tripped flowers is very similar to that occurring under natural conditions, but the similarity ends there. Naturally occurring pods contain approximately twice as many seeds. There are probably two main reasons for the lower number of seeds per pod. Firstly it was observed that the older flowers of the raceme were those most frequently tripped by the machine. This could be due to the greater ease of tripping of older flowers or because of the lack of bud protection. It was observed that a raceme containing a large number of buds as well as open flowers frequently escaped tripping by the machine because of the cushioning and protective effect afforded the flowers by the buds. Studies by Knowles (13) have shown that fewer pods are set when older flowers are tripped. Equally important is the fact that the major portion of the machine tripped flowers were probably self-pollinated. The results from Table 2 indicate that the distribution for the number of seeds per pod for the machine treatment is more similar to that for selfing than for crossing. The similarity of racemes and pods resulting from known selfing and machine tripping is further exemplified in Figs. 4 and 5.

As shown in Table 6 the data from the Sharpe and McKenzie fields differ in some respects. In the tests on the Sharpe field, once over with the machine tripped 46.3% of the flowers, 29% of which set pods while at the McKenzie field only

28.2% of the flowers were tripped but of them 47% set pods. The explanation probably is that there was a high concentration of wild bees at Tiger Lily, (a random count of bumble bees gave a figure of approximately 4000 per acre during warm sunny conditions). Consequently, there were fewer flowers left to wilt and the machine had to trip more young flowers. Relatively few bees were present, however, in the Sharpe field and the flowers persisted for a longer time. These older flowers, though they trip more easily, are known to be less fertile (13).

A review of the information gained about the machine shows that the machine does trip effectively but that it does not cross-pollinate appreciably. The ultimate result is that under conditions of the test it neither increased or reduced the yield. It is conceivable that if few or no pollinating bees were present the machine might be of some value. It is questionable if the seed from machine tripped flowers would be desirable because of the proportion of selfed seed. Some cross-pollination is brought about and improvements in this regard are needed if the machine is ever to be a success.

Test of Seedling Yields from Seed Obtained by Different Methods of Pollination

This test was conducted in the greenhouse with the objective of establishing if yields of forage would be noticeably depressed in plants from seed obtained from the mechanically tripped flowers. The results are summarized in Table 7.

Table 7

Yield in Green Weight of Seedlings from Seed Obtained by Different Treatments

Flower treatment	Yield, green weight (grams)
Open-pollination	6.4
Mechanically tripped	4.7
Selfed	6.7
Crossed	7.5

While the yield from the machine tripped seed was somewhat lower than was the yield from the other treatments, there were no significant differences in this test, (Table 8). This

is surprising since all reports indicate that at least a 30% drop in yield may be expected from one generation of selfing. The results obtained in this study are not reliable, however, because of the variability caused by factors other than those under test. Light, temperature and border effect gave a high variability, (e.g. column mean square in Table 8). The low percentage of germination indicates that probably only the most vigorous seeds and seedlings were those tested. The few crossed seeds occurring in the selfed and machine treatments may have been those actually tested, since these would be the most vigorous.

Table 8

The Analysis of Variance for Green Yield of Seedlings Resulting from Different Methods of Pollination

Variance due to:	D.F.	Mean square	F	F(.05%)
Rows	3	2.40	.93	4.76
Columns	3	12.38	4.78*	4.76
Treatment	3	5.62	2.17	4.76
Error	6	2.59		
Total	15			

* Significant at F(.05%).

The Effect of DDT on Bumble Bees

Three of the six bees introduced into the cage, immediately after the enclosed growth had been dusted, were still actively tripping after being caged for five days. Three of the bees were found dead, one the day following introduction and two the second day.

One bumble bee was found dead two days after the introduction into the cage in which the growth had been dusted two days prior to introduction of the bees. The other five continued to trip flowers and were released five days after introduction.

The bees showed no ill effects from exposure to DDT or from their stay in the cages. This preliminary study, therefore, indicates that bumble bees are quite tolerant of DDT dust.

Identification of Leaf-Cutter Specimens

A number of leaf-cutter bees collected in alfalfa fields were identified by Mr. C. E. Lilly, Department of Entomology, University of Alberta. Of 13 specimens collected, the following were found:

Megachile (Xanthosarus) perihirta Ckll.	6 ♀
Megachile (Sayapsis) pugnata Say.	1 ♀
Megachile (Delomegachile) vidua Sm.	3 ♀ 1 ♂
Megachile (Selomegachile) malanophaea Sm.	2 ♀

SUMMARY

1. Tripping is almost always a prerequisite to seed setting.

2. Automatic tripping was of little importance during the season of 1950. The exclusion of tripping and pollinating insects reduced the yield by 93%.

3. Leaf-cutter and bumble bees are the most important trippers of alfalfa and their presence is one of the most important factors in seed setting of alfalfa under northern Alberta conditions.

4. Honey bees are not important alfalfa trippers in Alberta but may increase the amount of automatic tripping that normally occurs.

5. Cross-pollination increased the number of seeds per flower seven times, pod setting 2.3 times and the seeds per pod 2.8 times over self-pollination.

6. Tripping by caged leaf-cutter bees and bumble bees results in cross-pollination. The majority of tripping occurring under natural conditions likewise results in cross-pollination indicating that insects are the main tripping and pollen carrying agents in alfalfa fields.

7. The mechanical tripper proved to be an efficient tripper but few pods resulted from the flowers so tripped. The higher percentage of the pods that do result are from self-pollinated flowers. Seed yields were not increased in strips treated with this machine, but the results are not considered conclusive.

8. No significant difference was obtained when forage yield of plants growing from seed resulting from different means of pollination was compared.

9. Bumble bees appear to be tolerant of DDT and continue tripping even though flowers are heavily dusted.

ACKNOWLEDGEMENTS

The writer wishes to express his gratitude to Dr. John Unrau for his assistance and guidance during the course of this study and in the preparation of the manuscript. I am indebted to the Alberta Seed Growers Co-op. Ltd., who provided a grant which made this study possible.

REFERENCES

1. AKERBERG, E. and LESINS, K. Insects pollinating alfalfa in central Sweden. Ann. Royal Agr. Coll. Sweden, 16:630-643. 1949.

2. BOLTON, J. L. A study of combining ability of alfalfa in relation to certain methods of selection. Sci. Agr. 28:97-126. 1948.

3. _____ and PECK, O. Alfalfa seed production in northern Saskatchewan as affected by lygus bugs, with a report on their control by burning. Sci. Agr. 26:130-137. 1946.

4. BRINK, R. A. and COOPER, D. C. The mechanism of pollination in alfalfa (Medicago sativa). Am. J. Botany, 23: 678-683. 1936.

5. _____. Partial self-incompatibility in Medicago sativa. Proc. Nat. Acad. Sci. 24: 497-499. 1938.

6. _____. Somatoplastic sterility in Medicago sativa. Science, 90:545-546. 1939.

7. COOPER, D. C., BRINK, R. A. and ALBRECHT, H. R. Embryo mortality in relation to seed formation in alfalfa (Medicago sativa). Am. J. Botany, 24:203-213. 1937.

8. COOPER, D. C. and BRINK, R. A. Partial self-incompatibility and the collapse of fertile ovules as factors affecting seed formation in alfalfa. J. Agr. Research, 60:453-472. 1940.

9. DWYER, R. P. and ALLMAN, S. L. Honey bees in relation to lucerne seed setting. Agr. Gaz., New South Wales, 44:363-371. 1932.

10. HADFIELD, J. W. and CALDER, R. A. Lucerne (Medicago sativa). Investigations relative to pollination in New Zealand. New Zealand J. Sci. Tech. 17:577-594. 1936.

11. HARE, Q. A. and WANSELL, G. H. Pollen collection by honey bees in the Delta, Utah, alfalfa seed-producing area. J. Am. Soc. Agron. 38:462-469. 1946.

12. JONES, L. M. and OLSON, P. J. Seed setting in Alfalfa. III. Sci. Agr. 23:315-321. 1943.

13. KNOWLES, R. P. The role of insects, weather conditions, and plant character in seed setting of alfalfa. Sci. Agr. 24:29-50. 1943.

14. LESINS, K. Investigations into seed setting of alfalfa at Ultuna, Sweden. (Unpublished paper from Sweden).

15. LINSLEY, E. G. Insect pollinators of alfalfa in California. J. Econ. Ent. 39:18-29. 1946.

16. _____ and MacSWAIN, J. W. Factors influencing the effectiveness of insect pollinators of alfalfa in California. J. Econ. Ent. 40:349-357. 1947.

17. _____. The effect of DDT and certain other insecticides on alfalfa pollinators. J. Econ. Ent. 40:358-363. 1947.

18. PEDERSEN, N. W. and TODD, F. E. Pollinating the seed crop. Seed World, May 6. 1946.

19. _____. Selection and tripping in alfalfa clones by nectar collecting honey bees. Agron. J. 41:247-249. 1949.

20. PIPER, C. V., EVANS, M. W., McKEE, R. and MORSE, W. J. Alfalfa seed production; pollination studies. U. S. Dep. Agr. Bull. 75. 1914.

21. SILVERSIDES, W. H. and OLSON, P. J. Seed setting in alfalfa. II. Sci. Agr. 22:129-134. 1941.

22. SMITH, R. F., MacSWAIN, J. W., LINSLEY, E. G. and PLATT, F. R. The effect of DDT dusting on honey bees. J. Econ. Ent. 41:960-971. 1949.

23. SORENSON, C. J. Lygus bugs in relation to alfalfa seed production. Utah Agr. Exp. Sta. Bull. 284. 1939.

24. STEVENSON, T. M. Problems relating to seed production of improved varieties of forage crops. Can. Seed Growers Assoc. Annual Rept. 41-43. 1948-1949.

25. _____ and BOLTON, J. L. Improved seed yield in alfalfa. Empire J. Exp. Agr. 15:82-88. 1947.

26. STITT, L. L. Three species of the genus Lygus and their relation to alfalfa seed production in southern Arizona and California. U. S. Dep. Agr. Bull. 741. 1940.

27. TYSDAL, H. M. Is tripping necessary for seed setting in alfalfa? J. Am. Soc. Agron. 32:570-585. 1940.

28. _____. Influence of tripping, soil moisture, plant spacing and lodging on alfalfa seed production. J. Amer. Soc. Agron. 38:515-535. 1946.

29. _____, KIESSELBACH, T. A. and WESTOVER, H. L. Alfalfa breeding. Nebraska Coll. Agr. Exp. Sta. Res. Bull. 124. 1942.

30. VANSELL, G. H. and TODD, F. E. Alfalfa tripping by insects. J. Am. Soc. Agron. 38:470-488. 1946.

31. Alfalfa Investigations, 1943. Mimeographed report from the Dominion Forage Laboratory, Saskatoon.

B29762